Surgical treatment of pseudoaneurysm of the thoracic aorta

Fernando A. Atik, MD,[a] Jose L. Navia, MD,[a] Lars G. Svensson, MD, PhD,[a] Pablo Ruda Vega, MD,[a] Jingyuan Feng, MS,[b] Mariano E. Brizzio, MD,[a] A. Marc Gillinov, MD,[a] B. Gosta Pettersson, MD, PhD,[a] Eugene H. Blackstone, MD,[a,b] and Bruce W. Lytle, MD[a]

Supplemental material is available online.

Objectives: To examine the clinical profiles, operative outcomes, and late results of patients with pseudoaneurysm of the thoracic aorta.

Methods: From 1990 to 2002, 60 patients underwent repair of aortic pseudoaneurysm: ascending aorta in 70%, ascending aorta and arch in 15%, descending aorta in 10%, and arch alone in 5%. Mean age was 53 ± 15 years, and 70% were men. Of these, 50 (83%) had undergone previous cardiac surgery, including 22 (37%) composite valve graft operations. The preferred cannulation site was femoral-femoral (n = 27, 45%), with deep hypothermic circulatory arrest in 62% and retrograde cerebral perfusion in 33%; more recently, however, axillary cannulation has been preferred.

Results: Principal etiologies were graft infection in ascending aorta pseudoaneurysm and trauma in descending aorta pseudoaneurysm. Fifteen patients (25%) presented with chest pain, 13 (22%) with heart failure, and 20% with moderate or severe aortic regurgitation. The pseudoaneurysm was resected and the aorta replaced (n = 45, 75%) or repaired (n = 15, 25%) using various methods. Hospital mortality was 6.7% (n = 4). Reexploration for bleeding was required in 8.3%, and 3.3% had postoperative stroke. At 30 days, 5 years, and 10 years, survival was 94%, 74%, and 60% and freedom from reoperation was 95%, 77%, and 67%, respectively.

Conclusions: Most patients with aortic pseudoaneurysm require ascending aorta and/or arch replacement, which can be accomplished with low operative mortality and morbidity. Long-term survival and freedom from reoperation in these young patients parallel those expected for complex cardiac and aortic disease.

From the Departments of Thoracic and Cardiovascular Surgery[a] and Quantitative Health Sciences,[b] The Cleveland Clinic Foundation, Cleveland, Ohio.

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Address for reprints: Jose L. Navia, MD, The Cleveland Clinic Foundation, Department of Thoracic and Cardiovascular Surgery, 9500 Euclid Ave/F24, Cleveland, OH 44195 (E-mail: naviaj@ccf.org).

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Pseudoaneurysm, or false aneurysm, of the thoracic aorta results from transmural disruption of the aortic wall, with the leak contained by surrounding mediastinal structures. Although it can be secondary to trauma[1] or infection,[2] previous cardiac surgery is the most frequent cause[3]; still, pseudoaneurysm occurs in fewer than 0.5% of all cardiac surgical cases.[4] Pseudoaneurysms are located at previous anastomotic sites, aortotomy sites, cannulation and venting sites, and proximal vein graft anastomotic sites.[5] Mechanisms implicated include infection, poor anastomotic technique, and intrinsic aortic wall disease.

Except for case reports[6,7] and small case series,[3,8-11] few studies have addressed this unusual complication. Surgical options vary according to pathologic features of the pseudoaneurysm, and operations can be challenging, especially in the presence of infection, previous cardiac surgery, or aortic valve regurgitation. Long-term survival after surgical treatment is unknown. Therefore, the purposes of this study were to examine the clinical profile, operative outcome, and late results of patients surgically treated for pseudoaneurysm of the thoracic aorta.

Patients and Methods

From 1990 to 2002, 60 patients underwent surgery for pseudoaneurysm of the thoracic aorta at The Cleveland Clinic Foundation. Etiology was confirmed by surgical or pathologic

Abbreviations and Acronyms
CL = confidence limits
CVIR = Cardiovascular Information Registry

reports. Preoperative, operative, and postoperative data were obtained from the prospective Cardiovascular Information Registry (CVIR), which has been approved for research by the Institutional Review Board of the Cleveland Clinic. Systematic follow-up was obtained in part through consultations for echocardiographic assessment at the Cleveland Clinic as well as through reports from referring cardiologists and systematic formal interviews with patients and family members. Follow-up was obtained for all patients. Mode of death was assigned through review of clinical records and death certificates. Mean follow-up was 4.0 ± 3.2 years, with 10% followed more than 8.8 years.

Forty-two patients (70%) were men, and mean age was 53 ± 15 years (Table 1). The pseudoaneurysm was located in the ascending aorta in 42 (70%), ascending aorta and arch in 9 (15%), arch alone in 3 (5%), and descending aorta in 6 (10%).

Fifty patients (83%) had previous cardiac surgery (34 had one previous operation, 13 had two, 2 had three, 1 had four, and 1 had five). These included aortic root replacement in 22 (37%) and supracoronary ascending aortic replacement in 9 (15%) for aortic dissection (15 patients), aortic valve endocarditis (6 patients), and aortic aneurysm (27 patients). Four patients (6.7%) previously had deep sternal wound infection requiring extensive debridement and omental or pectoralis flap reconstruction. Two patients had undergone heart transplantation.

Almost 80% of patients had the operation performed within 2 weeks of diagnosis of aortic pseudoaneurysm (Figure 1). Operation was performed on an emergency basis in 8 patients (13%) because of signs of cardiovascular collapse or systemic hypoperfusion.

TABLE 1. Patient characteristics

Characteristic	No.	%
Demography		
Age (y), mean ± SD	53 ± 15	
Male	42	70
Cardiac comorbidity		
NYHA functional class		
I	18	30
II	21	35
III	10	17
IV	11	18
Previous cardiac operation		
Aortic root replacement only	17	28
Aortic root + ascending + arch	2	3.3
Aortic root + proximal descending	1	1.7
Aortic root + arch + proximal descending	1	1.7
Supracoronary ascending + aortic valve	7	12
Supracoronary ascending + arch	2	3.3
Descending only	1	1.7
CABG only	3	5
CABG + aortic root replacement	1	1.7
Aortic valve surgery only	8	13
Aortic valve + mitral valve surgery	2	3.3
Heart transplant	2	3.3
Carotid-subclavian shunt*	1	1.7
Aortic regurgitation grade†		
None	16	39
1+ (trivial)	8	19.5
2+ (mild)	9	22
3+ (moderate)	2	4.9
4+ (severe)	6	14.6
Endocarditis‡	19	35
Marfan syndrome	2	3.3
Noncardiac comorbidity		
Treated diabetes§	3	
Hypertension‖	36	63
COPD¶	14	33
Peripheral vascular disease	15	25
Chronic renal failure#	7	12

CABG, Coronary artery bypass grafting; *COPD*, chronic obstructive pulmonary disease; *NYHA*, New York Heart Association; *SD*, standard deviation. *For aortic occlusive disease. †Data available in 41 patients. ‡Data available in 54 patients. §Data available in 58 patients. ‖Data available in 57 patients. ¶Data available in 43 patients. #Defined as preoperative serum creatinine >2 mg · dL^{-1} or preoperative dialysis.

Surgical Technique

Intraoperatively, patients were routinely monitored with a pulmonary artery thermodilution catheter and transesophageal echocardiography. Surgical approach depended on location of the pseudoaneurysm, whether the patient had a previous cardiac operation, whether the pseudoaneurysm penetrated or was near the undersurface of the sternum, and presence of aortic regurgitation, mediastinitis, endocarditis, or associated cardiac problems requiring concomitant surgical treatment.

Median sternotomy was performed in all patients with pseudoaneurysms located on the ascending aorta or aortic arch, except 1 in whom a clamshell incision was used. Right anterior thoracotomy was performed in conjunction with median sternotomy in 3 patients to achieve better control of the aorta during chest reentry. No cardiac or other structural injuries were documented.

Surgical approach to pseudoaneurysm of the descending aorta was left posterolateral thoracotomy through the third or fourth intercostal space in 6 patients and median sternotomy in 1 patient who had an infected prosthetic graft previously implanted in the distal aortic arch and proximal descending aorta.

Arterial cannulation site was the femoral artery in 27 patients (45%), axillary or subclavian artery in 18 (30%), and aorta or brachiocephalic trunk in 12 (20%). Left pulmonary artery–to–descending aorta bypass was used in 2 patients (3.3%). In 1 patient with pseudoaneurysm of the descending aorta, cardiopulmonary bypass was not used. Because of the danger posed by opening the chest with proximity of the pseudoaneurysm to the undersurface of the sternum, aortocutaneous fistula, or mediastinitis, hypothermic low-flow cardiopulmonary bypass was instituted before sternal reentry in 26 (43%), and this proceeded to deep hypothermic circulatory arrest in 8 (31% of these). During cooling while the heart was freed from adhesions, ventricular distention was moni-

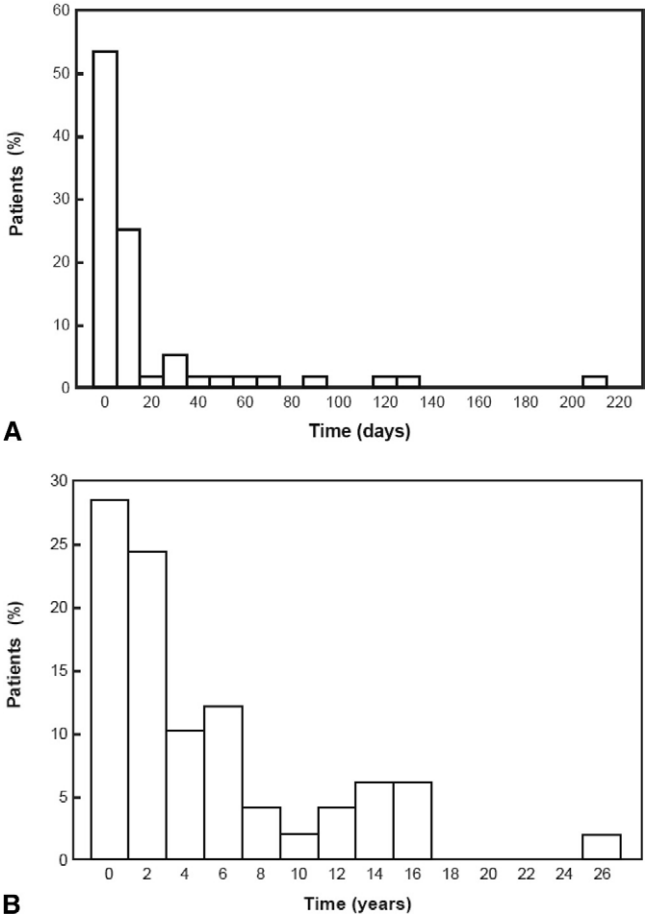

Figure 1. Death after surgical treatment of pseudoaneurysm of the aorta. A, Survival. Each death is represented by a *circle*, which is a Kaplan-Meier estimate. *Vertical bar* represents asymmetric 68% confidence limits (CL, equivalent to 1 standard error). *Solid line* is a parametric survival estimate enclosed within dashed 68% CLs. Numbers in *parentheses* are number of patients remaining at risk. B, Hazard function (instantaneous risk) for death. *Solid line* is the hazard estimate enclosed within 68% CLs.

TABLE 2. Operative procedures (n = 60)

Procedure	No.	%
Aortic procedure		
Replacement	46	77
Root + ascending	14	23
Root + ascending + arch	5	8.3
Aortic valve + ascending	5	8.3
Ascending only	8	13
Ascending + arch	3	5
Ascending + arch + descending	1	1.7
Arch only	4	6.7
Descending only	5	8.3
Extra-anatomic bypass	1	1.7
Repair	14	23
Autologous pericardium	3	5
Allograft	4	6.7
Dacron	2	3.3
Primary	5	8.3
Arterial cannulation site		
Femoral	27	45
Axillary or subclavian	18	30
Aorta or brachiocephalic trunk	12	20
Left PA–descending aorta bypass	2	3.3
None	1	1.7
Cerebral protection		
Hypothermic circulatory arrest	37	62
Retrograde brain perfusion	20	33
Antegrade brain perfusion	2	3.3
Associated procedures*		
Aortic valve replacement	20	33
Aortic valve repair	4	6.7
CABG	11	18
Mitral valve repair	4	6.7
Mitral valve replacement	1	1.7
Tricuspid valve repair	1	1.7

CABG, Coronary artery bypass grafting; *PA*, pulmonary artery. *Not mutually exclusive.

tored by pulmonary artery pressures and transesophageal echocardiography, especially in patients with severe aortic regurgitation. In 3 of these patients, a small left anterior thoracotomy was performed to vent the left ventricular apex.

Deep hypothermic circulatory arrest was used in 37 patients (62%), with retrograde brain perfusion in 20 (54% of these) and antegrade brain perfusion in 2 (5.4% of these). Details of the operations are shown in Table 2.

The segment of aorta in which the pseudoaneurysm was located was replaced with a tube graft in 46 patients (77%) and repaired with or without a patch in 14 (23%). Replacement was performed in patients with large pseudoaneurysms, mediastinitis, graft infection, associated prosthetic aortic valve endocarditis, and after Bentall operations. Aortic repair was performed after debriding the pseudoaneurysm sac and trimming its edges. Primary closure with interrupted pledget-supported sutures was performed in 5 patients (8.3%) with small defects and no sign of infection. Patch repair was performed in 9 patients (15%) with larger defects or localized infected material that could be debrided safely without risk of recurrence. Septic pseudoaneurysms were preferentially replaced or repaired with allografts (79%), followed by bovine or autologous pericardium patches (12.5%) and prosthetic material (8.5%).

Concomitant surgery (see Table 2) included aortic valve replacement in 28 patients (47%), aortic valve repair in 4 (6.7%), and coronary artery bypass grafting in 11 (18%). Mean cardiopulmonary bypass and aortic clamping times were 173 ± 74 minutes and 112 ± 50 minutes, respectively. Deep hypothermic circulatory arrest time was 28 ± 14 minutes.

Data Analysis

Descriptive data are presented as means and standard deviations for continuous variables (medians with 15th and 85th percentiles for variables with skewed distributions) and frequencies and per-

centages for categorical variables. Confidence limits (CL) of proportions are equivalent to 1 standard error (68%). Nonparametric estimates of survival and freedom from reoperation were obtained by the Kaplan-Meier method. A parametric method was used to resolve the number of phases of instantaneous risk of death and of reoperation (hazard function) and to estimate shaping parameters.[12] (For additional details, see http://www.clevelandclinic.org/heartcenter/hazard.)

Results

Clinical Presentation

Clinical presentation varied according to location of the pseudoaneurysm (Table E1). Heart failure, chest pain, and sepsis were the most common manifestations of pseudoaneurysms of the ascending aorta. Heart failure was more severe and compounded by associated valve disease, coronary artery disease, or left ventricular dysfunction (P = .01). By contrast, descending pseudoaneurysm was most commonly manifested by left main bronchus compression and incidental finding on chest radiograph; all such patients had a history of deceleration trauma. Postoperative pseudoaneurysms, located in the ascending aorta or aortic arch, and whether infected or not, occurred within 2 years of the initial operation in more than half of the patients (Figure 2, *B*).

Pseudoaneurysm Site and Etiology

Pseudoaneurysm site (Table 3) was proximal to composite valve graft anastomosis or periprosthetic leak and distal aortic anastomosis in 60% of patients. Infection was the predominant cause (Table 3); almost half of the patients had a history of native or prosthetic valve endocarditis or mediastinitis. Only 42% of septic pseudoaneurysms had positive blood cultures; *Staphylococcus aureus* was the most prevalent microorganism.

Surgical Outcomes

In-hospital outcomes. Hospital mortality was 6.7% (n = 4, CL 3.4%-12%; Table 4). Causes of death were multiple organ system failure (n = 2), pulmonary embolism (n = 1), and bleeding from coagulopathy (n = 1).

Five patients (8.3%) required reexploration for bleeding. Postoperative intra-aortic balloon pumping was required in 1 patient (1.7%) with cardiogenic shock despite optimum inotropic support. Fourteen (23%) had prolonged mechanical ventilation, 1 (1.7%) had acute renal failure requiring dialysis, 2 (3.3%) experienced stroke, and 4 (6.7%) sepsis. Three patients (5%) had deep sternal wound infection requiring omental flaps. Median intensive care unit and postoperative hospital lengths of stay were 3 days and 11 days, respectively. Among hospital survivors, 42 (75%) were discharged home. The remaining were discharged to nursing homes or another hospital for rehabilitation or intravenous antibiotics.

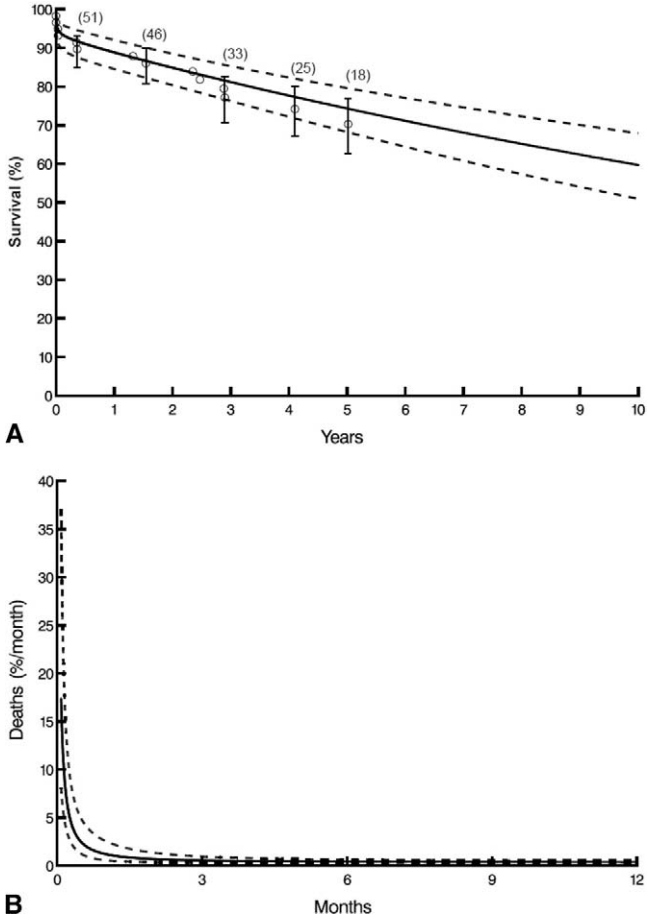

Figure 2. Timing of aortic pseudoaneurysm. A, Interval from diagnosis to aortic pseudoaneurysm surgery. B, Interval between previous cardiac operation and aortic pseudoaneurysm surgery.

Time-related outcomes. Fifteen additional patients died during follow-up. These plus in-hospital deaths yielded survivals of 93%, 89%, 81%, 74%, and 60% at 30 days and 1, 3, 5, and 10 years (Figure 1). The hazard function consisted of two phases: an early steeply declining phase and a constant hazard phase (Figure 1, *B*). Death was cardiovascular related in 7 patients: heart failure in 4, aortic dissection in 2, and ventricular arrhythmia in 1. By a modulated renewal process analysis, reoperation had no discernible influence on mortality (P = .4).

Freedom from reoperation was 92%, 87%, 82%, 77%, and 68% at 3 months and 1, 3, 5, and 10 years (Figure 3). Reoperation was related to aortic disease in 8 patients. Recurrent pseudoaneurysm occurred in 5 patients and descending or thoracoabdominal aneurysm or dissection in 3. Mediastinitis was associated with all but 1 recurrent pseudoaneurysm. All of them had had initially septic pseudoaneurysms treated with composite grafts (n = 2) or allograft

TABLE 3. Pseudoaneurysm of the aorta site and etiology

Site and etiology	No.	%
Site		
Proximal composite valve graft anastomosis	19	32
Distal aortic anastomosis	17	28
Coronary button reimplantation or vein graft anastomosis	10	17
Aortic isthmus	5	8
Proximal supracoronary ascending aorta	5	8
Aortic cannulation site	2	3
Proximal aortic arch	1	2
Aortotomy	1	2
Etiology		
Aortic valve endocarditis	14	23
Mediastinitis	12	20
Aortic dissection, cystic medial necrosis or mucoid degeneration	11	19
Trauma	6	10
Technical imperfection	5	8
Unknown	12	20

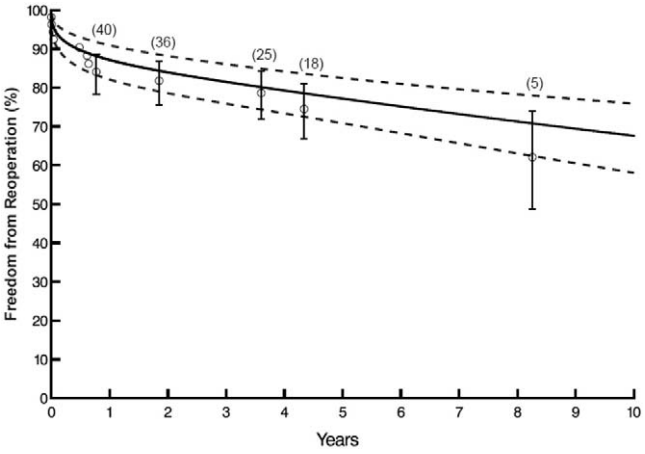

Figure 3. Freedom from reoperation after pseudoaneurysm repair or replacement.

patch repair (n = 2). However, there was no evidence that septic pseudoaneurysm was associated with worse survival ($P = .9$) or lower freedom from reoperation ($P = .4$).

Discussion

Principal Findings

Clinical presentation. As in other series, most patients in this study presented with chest pain or heart failure.[11] Chest pain was caused by compression of surrounding structures, aortic stretching, or cardiac ischemia. Heart failure was related to valvular regurgitation, compression of surrounding structures, and cardiac compression.

Although an incidental finding of a descending chronic pseudoaneurysm is common in patients with a remote history of trauma, compression of the left main bronchus associated with hemoptysis was noted in our series as well as in others.[13] Hemoptysis may be intermittent[14] if clots or thrombi block the flow of blood from pseudoaneurysm into bronchus. However, massive hemoptysis can occur.[8] This is the hallmark of active arterial bleeding and may occur several years after a thoracic aortic operation.[15]

About 20% of all pseudoaneurysm patients presented with symptoms related to sepsis, the most common cause of pseudoaneurysm in our and others' experience.[10]

Pseudoaneurysm site and etiology. Disruption of the aortic wall may be related to etiology and type of previous operation. Although leak at the aortic cannulation site has been reported as the most common cause,[3] we found proximal and distal ascending aortic anastomotic disruptions were also common. This can be explained by our unique population and referral pattern. Most patients developed pseudoaneurysm in the ascending aorta after previous cardiac and aortic operations. One quarter had aortic dissection, and several had postoperative deep sternal wound infection. These conditions increase risk of suture dehiscence, leading to pseudoaneurysm formation.

Less frequently reported sites of pseudoaneurysm include saphenous vein graft anastomotic site, coronary button reimplantation site, aortotomy site, and aortic vent sites.[3,16-18]

Surgical outcome. Our surgical mortality is lower than that reported by others.[3,8-11] Occurrence of postoperative bleeding, stroke, or renal failure was uncommon and intensive care unit and hospital lengths of stay were short. These favorable outcomes can be attributed to thorough surgical planning, adequate myocardial and cerebral protection, and excellent multiprofessional perioperative care.[19] Long-term survival was comparable with that expected for complex aortic surgery.[20]

TABLE 4. Outcomes of surgical treatment of pseudoaneurysm of the aorta (n = 60)

Outcome	No.	%	CL
Mortality	4	6.7	3.5-12
Stroke	2	3.3	0.2-5.4
Intra-aortic balloon pump	1	1.7	0.3-5.4
Renal failure	1	1.7	0.3-5.4
Respiratory failure	14	23	18-30
Sepsis	4	6.7	3.5-12
Reexploration for bleeding	5	8.3	4.8-14
Intensive care unit stay (median days)	3	—	1, 9[a]
Postoperative hospital stay (median days)	11	—	6, 28[a]

CL, 68% confidence limits. * 15th and 85th percentiles.

Surgical Treatment

Surgical treatment is complex, but the keystones of successful treatment are (1) preventing cardiac injury during chest opening, with consequent exsanguination, and (2) protecting the brain. Surgical approach depends on location of the pseudoaneurysm, its proximity to the undersurface of the sternum, and presence of associated cardiac problems. When the pseudoaneurysm is located on the ascending aorta or aortic arch, median sternotomy is our incision of choice, although we frequently use a minimally invasive approach for reoperations.[21] Auxiliary right anterior thoracotomy is useful when the pseudoaneurysm is closely related to the undersurface of the sternum; however, a minimally invasive "J" incision achieves the same right ventricle protection.[22] Hypothermic low-flow cardiopulmonary bypass or deep hypothermic circulatory arrest is used in most of our patients. Although the majority of patients are cannulated via femoral vessels, the right axillary or subclavian artery and femoral vein have become the cannulation sites of choice in recent years.[23]

When the pseudoaneurysm is located in the descending aorta, our approach is through a standard left posterolateral thoracotomy. However, we frequently use right subclavian artery cannulation for arterial inflow in difficult cases.

Patients with severe aortic regurgitation pose a problem for myocardial protection during chest reentry, especially if hypothermic cardiopulmonary bypass is necessary. Slow cooling phase and use of lidocaine delay onset of ventricular fibrillation. Real-time transesophageal echocardiography and pulmonary artery pressure monitoring are useful in detecting ventricular distention, which may require left ventricular apical venting through a small left thoracotomy. The drawback of this strategy is that cooling and brain protection may be poor until the aorta is clamped and myocardial protection is established. Additionally, left ventricular venting may not be efficient enough to prevent distention. For those reasons, some surgeons advocate port-access techniques, including endoluminal balloon occlusion of the aorta, antegrade cardioplegia administration, and left ventricular venting before chest opening.[24,25] Some use balloon occlusion of the ascending aorta and transjugular coronary sinus cannulation for retrograde cardioplegia to augment myocardial protection.[25] Left thoracotomy is another approach for these difficult reoperations.[26]

Aortic graft replacement is our treatment of choice for most patients. Indications included large pseudoaneurysms and graft infection, with or without aortic valve endocarditis. If endocarditis is present, the operation follows general principles of extensive debridement of all infected and necrotic tissues, extensive irrigation, and use of allograft conduits[27] (two combined allografts were necessary when, in addition to the aortic root, other segments of ascending aorta or aortic arch needed to be replaced). Extra-anatomic grafting was used in only one patient with an infected descending aortic graft. Life-long antibiotic treatment is indicated. In the presence of infected grafts, viable omentum and muscle flaps can be used.[28] They were eventually indicated in the presence of severe osteomyelitis that precluded primary chest closure.

Pseudoaneurysm repair without tubular grafts can be safely performed for smaller defects. In our experience, most cases of localized infection that could be debrided allowed for patch closure. Primary closure is also possible when densely fibrotic pseudoaneurysm edges are present.

Limitations

This is a single-institution clinical cohort study of a relatively small number of surgically treated patients. It was not possible to estimate true prevalence of aortic pseudoaneurysm (the "denominator") because only patients diagnosed and referred for surgery were included. Percutaneous interventions that might have been performed were not investigated.

Conclusions

Aortic pseudoaneurysm is an uncommon pathologic condition. Most patients are young but have had previous cardiovascular surgery; one third have endocarditis. Most require ascending aorta replacement. Survival and freedom from reoperation are similar to those expected for complex combined cardiac and aortic disease.

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TABLE E1. Clinical presentation of pseudoaneurysm of the thoracic aorta

Location	No.	%
Ascending aorta		
Heart failure	15	36
Chest pain	9	21
Sepsis	8	19
Incidental finding	3	7
Bleeding or drainage from wound	2	5
Superior vena cave syndrome	2	5
Pulsatile suprasternal mass	2	5
Stroke	1	2
Ascending aorta and arch		
Sepsis	4	44
Chest pain	4	44
Stroke	1	12
Arch		
Tracheal compression	1	33
Chest pain	1	33
Pulsatile suprasternal mass	1	33
Descending aorta		
History of trauma	6	100
Left main bronchus compression	2	33
Incidental finding	2	33
Hemoptysis	1	17
Chest pain	1	17